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REPORT NO. 3-81

(6) STANDARDIZED NEDU UNMANNED UBA TEST PROCEDURES AND PERFORMANCE GOALS.

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report represents the most recent developments in a continuing effort by NEDU to accurately simulate the physiology of a working diver during unmanned UBA performance testing. The unmanned test procedures outlined in this document simulate the physiology of a diver performing graded exercise from light to extreme work rates. CO_2 absorbent canister duration studies duplicate the standard NEDU manned test scenario.

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Performance goals are listed for all types of UBA according to their operational characteristics. These goals do not represent minimum acceptable performance levels. Rather, they are goals which when met by a piece of life support equipment, will insure that the UBA is not the limiting factor in diver performance. Acceptance of any given piece of equipment for military or commercial use must be based on specific operational requirements.

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Glossary

ATA	Atmospheres Absolute
°C	Degrees Centigrade
CM	Centimeters
CmH20	Centimeters of Water Pressure
CO2	Carbon Dioxide
dBA	Sound Level in Decibels ('A' Scale)
EDF	Experimental Diving Facility
°F	Degrees Farenhiet
FREQ	Frequency (Breaths Per Minute)
FSW	Feet-of-Seawater
HeO2	Helium-Oxygen Gas Mixture
Kg.M/ℓ	(Breathing Work) Kilogram Meters Per Liter of Respired Volume
ℓ	Liters
LPM	Liters Per Minute
LPS	Liters Per Second
M	Meter
MIN	Minutes
NCSC	Naval Coastal Systems Center
NEDU	Navy Experimental Diving Unit
O/B	Overbottom Pressure
P	Ambient Pressure
ΔP	Pressure Differential
ρ	Density
$\propto$	Proportional To
π	3.14
psid	Pounds Per Square Inch Differential

psig	Pounds Per Square Inch Gauge
RMV	Respiratory Minute Volume Measured in Liters Per Minute
% SEV	Percent Surface Equivalent Volume
SCUBA	Self-Contained Underwater Breathing Apparatus
STPD	Standard Temperature and Pressure
TV	Tidal Volume Measured in Liters
UBA	Underwater Breathing Apparatus
VCO2	Metabolic Carbon Dioxide Production Measured in Liters Per Minute
VO2	Metabolic Oxygen Consumption in Liters Per Minute
V Max	Maximum Flow Rate

Abstract

This report represents the most recent developments in a continuing effort by NEDU to accurately simulate the physiology of a working diver during unmanned UBA performance testing. The unmanned test procedures outlined in this document simulate the physiology of a diver performing graded exercise from light to extreme work rates. CO_2 absorbent canister duration studies duplicate the standard NEDU manned test scenario.

Performance goals are listed for all types of UBA according to their operational characteristics. These goals do not represent minimum acceptable performance levels. Rather, they are goals which when met by a piece of life support equipment, will insure that the UBA is not the limiting factor in diver performance. Acceptance of any given piece of equipment for military or commercial use must be based on specific operational requirements.

I. INTRODUCTION

The contents of this report represents the most recent developments in a continuing effort by NEDU to accurately simulate the physiology of a working diver during unmanned UBA performance tests. Use of a breathing simulator to evaluate diving life support equipment has been an accepted test method for over 20 years. However, only recently has the technology been available in manned underwater testing to evaluate all pertinant physiological parameters necessary to develop accurate unmanned test scenarios. In addition, prior performance goals for UBA's were not based on actual in-water manned tests at depth. Rather they were extrapolations from (1) scientific theory and (2) tests conducted at one atmosphere pressure.

Since 1976 extensive research and development in the above areas not only by NEDU but also the NCSC Hydrospace Laboratory in Panama City, Florida and University of New York at Buffalo has led to the formation of the unmanned test procedures and performance goals contained herein. A cross-section of the recent test reports on both manned and unmanned evaluations which led to the production of this document is given in the Reference Section. The test procedures in Section II have been found to accurately represent the physiological reactions of a diver performing graded exercise on a bicycle ergometer at levels ranging from light to extreme work. CO_2 absorbent canister duration studies duplicate the standard NEDU manned test scenario and have consistently produced comparable manned/unmanned canister bed lifes when test conditions, i.e. depth and water temperature, were similar.

The various types of UBA are broken down into 5 categories (Section III) according to their operational characteristics. Every type of diver-worn underwater breathing apparatus available either to the military or commercial diving industry is covered in one of the 5 categories. Performance goals vary with each category of equipment depending upon their breathing gas mixture, depth of operation and/or inherent state-of-the-art design limits. These performance goals have been proven reasonable in both manned and unmanned testing and have been met in each category by existing commercially available and/or military diving equipment. They do not represent minimum acceptable performance levels. Rather, they are goals which when achieved will ensure that the UBA is not a limiting factor in diver performance. Acceptance of any given piece of equipment for military or commercial use must still be based on specific operational requirements.

<u>It is important to note that this report is meant to be a dynamic document. As technology improves and experience is gained, it will be updated to reflect any changes which will improve the unmanned test simulation or more accurately reflect reasonable UBA performance goals.</u> In keeping with this policy of continuously updating NEDU unmanned test standards and performance goals, Appendix A contains a list of previous NEDU reports on similar subjects which are superceded by this document.

II. TEST PROCEDURES

A. Breathing Simulator Set Points and Instrumentation

Unmanned testing should be done using standardized well defined combinations of frequency (FREQ) in breaths-per-minute, tidal volume (TV), and metabolic rates ($\dot{V}O_2$) on a breathing machine. The respiratory minute volume (RMV) is simply the product TV multiplied by FREQ. The CO_2 production and O_2 consumptions are assumed to be equal and are indicative of what would be expected of subjects performing graded exercise underwater. Two basic tests are done, (1) breathing work-per-liter/inhaled CO_2 studies and (2) CO_2 absorbent canister duration studies. Table 1 lists the standardized test conditions for breathing work/inhaled CO_2 studies and, Table 2 lists standardized test conditions for CO_2 absorbent canister duration studies on closed- and semi-closed circuit UBA.

All testing should be conducted using a breathing simulator with a sinusoidal waveform and an inhalation/exhalation ratio of 1.0. A typical unmanned test setup is shown in Figure 1 with a list of instrumentation given in Table 3. Table 4 lists the address of each instrumentation manufacturer outlined in Table 3. Standardization of specific models and brands of test equipment is unnecessary as long as the test equipment used has performance specifications comparable to those listed in Table 1.

B. Test Plan for Breathing Work/Inhaled CO_2 Studies

(1) Measured Parameters:

(a) Oronasal or mouthpiece ΔP

(b) Breath-by-breath oronasal or mouthpiece CO_2 levels

(c) ΔP across other breathing loop components as required

(2) Controlled Parameters:

(a) Water temp: ambient

(b) Depth: 1 ATA increments to max test depth

(c) Breathing machine setup: see Table 1

(d) Relative humidity: ambient

(e) UBA orientation: diver in vertical position (Note: For certain closed-circuit UBA's measurement of static load should also be made in the prone position.)

TABLE 1

BREATHING RESISTANCE TEST CONDITIONS

VO2 AND VCO2 LPM STPD	RMV LPM	TV ℓ	FREQ	DIVER WORK RATE
0.90	22.5	1.50	15	Light
1.60	40.0	2.00	20	Moderate
2.50	62.5	2.50	25	Moderately Heavy
3.00	75.0	2.50	30	Heavy
3.60	90.0	3.00	30	Extreme *

* Ninety RMV represents an extreme work rate which can be sustained only for short durations. It has been achieved on manned wet dives at depths up to 1800 FSW and is included as a test parameter to determine the upper limits of a UBA's life support characteristics.

TABLE 2

CANISTER DURATION STUDY TEST CONDITIONS

DURATION (MIN)	VO2 AND VCO2 LPM STPD	RMV LPM	TV ℓ	FREQ	DIVER WORK RATE
4	0.90	23.0	2.00	11.5	Light
6	2.00	50.0	2.00	25.0	Moderate

TABLE 3

TEST EQUIPMENT

1. Breathing simulator with piston position transducer, CO_2 add system and exhaled gas temperature/humidity controller.

2. VALIDYNE Model DP-15 pressure transducer (oral pressure, canister pressure drop and inhalation/exhalation hose pressure drops).

3. Wet test box.

4. The heating and cooling systems will be used to control water temperature during the canister duration tests.

5. MFE Model 715M X-Y plotter for generating pressure-volume loops.

6. VALIDYNE Model CD-19 transducer readout.

7. BECKMAN 865 Infrared Analyzer for analysing CO_2 out of CO_2 absorbent canister.

8. Hyperbaric chamber complex.

9. ROYLYN gas supply pressure gauge (0.25% accuracy).

10. ROYLYN depth gauge (0.25% accuracy).

11. Test UBA: MK-16 Closed-Circuit Mixed-Gas UBA.

12. HYGRODYNAMICS Model 15-3050 Relative Humidity Sensor.

13. GOULD Brush Model 2600 Strip Chart Recorder.

14. YSI Model 700A Series Thermisters for monitoring CO_2 absorbent canister bed temperature.

15. DIGITEC Model 5820 Thermister Readouts.

16. APPLIED ELECTROCHEMISTRY Model S3-A oxygen analyser for measuring metabolic oxygen consumption.

17. PERKIN ELMER Model MGA 1100 Mass Spectrometer for breath-by-breath analysis of CO_2 washout in UBA oral cavity dead space.

TABLE 4

MANUFACTURER ADDRESSES

1. Validyne Engineering Corporation
   18819 Napa Street
   Northridge, CA 91324
   Model DP15 Pressure Transducer
   Model CD19 Carrier Demodulator

2. MFE Corporation
   Kewaydin Drive
   Salem, NH 03079
   Model 715 Plotamatic X-Y Recorder

3. Beckman Instruments, Inc.
   2500 Harbor Boulevard
   Fullerton, CA 92634
   Model 865 CO_2 Analyzer

4. 3D Instruments, Inc.
   15542 Chemical Lane
   Huntington Beach, CA 92649
   Roylyn Precision Pressure Gauges (0.25% accuracy)

5. American Instrument Company
   8030 Georgia Avenue
   Silver Springs, MD 20910
   Hygrodynamics Hygrometer Indicator (Model 15-3050)

6. Gould Inc.
   Instrument Systems Division
   3631 Perkins Avenue
   Cleveland, OH 44114
   2600 Series Recorder

7. United Systems Corp.
   918 Woodley Road
   Dayton, OH 45403
   Digitec Model 5820 Digital Thermistor Thermometer with Series 700A Thermistor Probes

8. Applied Electrochemistry
   735 N. Pastoria Avenue
   Sunnyvale, CA 94086
   Model S-3A Oxygen Analyzer

9. Perkin Elmer
   2771 Garey Avenue
   Pomona, CA 91766
   Model MGA 1100

TABLE 4

MANUFACTURER ADDRESSES (continued)

10. Brooks Instrument Division
    Emerson Electric Company
    Hatfield, PA 19440
    Model 5810 Thermal CO_2 Mass Flow Meter

11. Merriam Instruments
    10920 Madison Avenue
    Cleveland, OH 44101
    Model LFE Laminar Flow Elements

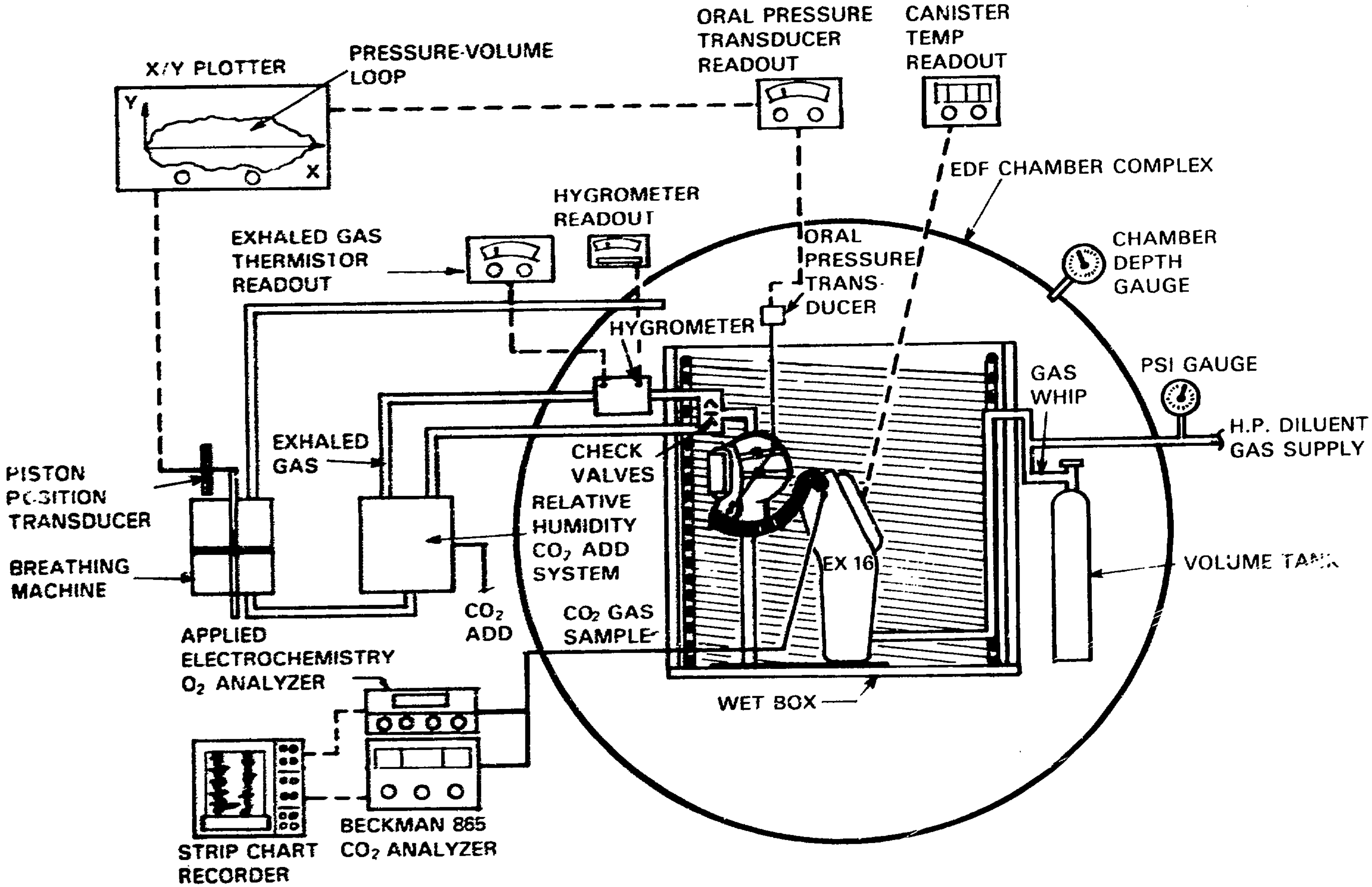


FIGURE 1 – TEST SETUP

(3) Procedure: At each depth of interest, testing under a given set of breathing simulator set points is done until stable readings are obtained.

(4) Data presentation:

(a) Typical ΔP waveforms

(b) Typical oronasal CO_2 waveform

(c) Typical pressure-volume loops

(d) Plots of peak inhalation/exhalation ΔP vs. depth at each RMV

(e) Work-of-breathing per liter (kg-m/ℓ) vs depth at each RMV

Note: Work-of-breathing is computed from the area inscribed by the pressure volume loops according to the formula:

$$\text{Work}/\ell \ (\text{kg-m}/\ell) = \frac{\text{Area}}{100\ (\text{TV})}$$

Area in units of cm^2
TV in units of ℓ

(f) End expired and inspired oronasal CO_2 levels in % Surface Equivalent Value (SEV) (mean of 10 breaths) vs depth of each RMV

C. Test Plan for CO_2 Absorbent Canister Duration Studies:

(1) Measured Parameters:

(a) CO_2 (% SEV) levels at absorbent canister inlet and outlet

(b) Oronasal or mouthpiece CO_2 levels (% SEV) (breath by breath)

(c) Canister bed temperatures as required

(2) Test conditions:

(a) Water temp - within 2°F of desired temperature: Normal temperature test points are 30, 35, 40, 50, 60, and 70°F

(b) Depths - as required

(c) Breathing Machine setup: See Table 2

Note: Since tidal volume changes cannot be made rapidly on the Breathing Machine, this parameter is kept at 2ℓ for both test conditions.

(d) Relative humidity: 90 ± 2%

(e) UBA orientation: diver vertical

(f) Exhaled gas temperature: control maintained using the formula (expired gas temperature equals 24 + 0.32 times inspired gas temperature where inspired gas temperature is at ambient water temperature in umbilical-supplied UBA and assumed to be 10°C above ambient water temperature in self-contained apparatus): $T_{exp} = 24 + 0.32\ T_{in}$ (degrees centigrade)

NOTE: If the inspired breathing gas is heated by external means, thermistors must be used to determine Tin, and this value used in the equation.

(3) Procedure: At each depth and temperature of interest, 4 minutes with the Breathing Machine setup in light work condition are followed by 6 minutes with Breathing Machine setup of moderate work (0.9 and 2.0 $\dot{V}CO_2$, respectively) until a CO_2 level of at least 1% SEV is observed in the canister outlet. CO_2 is added continuously through the Breathing Machine exhalation hose at the add rates shown in Table 2.

(4) Data presentation:

(a) Typical oronasal CO_2 waveforms

(b) Canister outlet CO_2 levels (% SEV) vs time

(c) Canister inlet CO_2 (% SEV) levels vs time

(d) Canister bed temperature vs time

(e) Times at which CO_2 level (% SEV) reaches 0.5 and 1.0% under each test condition

III. UNMANNED PERFORMANCE GOALS

A. UBA Categories. The various types of UBA are categorized into 5 groups according to their operational characteristics. Performance goals for each group are defined in Section B. Goals vary with each group depending upon maximum operating depth, breathing gas mixture and/or inherent state-of-the-art design limits.

Category 1: Open-circuit demand SCUBA regulators

Category 2: Open-circuit umbilical-supplied demand UBA (*i.e. full-face masks and dry helmets)

Category 3: Open-circuit umbilical-supplied free-flow UBA (i.e. full-face masks and dry helmets)

Category 4: Closed and semi-closed circuit diver breath driven UBA, *i.e. MK-15 and MK-11 type rigs with full face masks, mouthpiece or dry helmets

Category 5: Closed- and semi-closed circuit ejector or pump-driven UBA (push-pull) (i.e. MK-12 mixed-gas or MK-14 type rigs with dry helmets)

*Note: Full-face masks and dry helmets in categories 2 and 4 are assumed to have built-in oral-nasal masks or mouthpieces.

Performance goals in either work-of-breathing per liter and/or maximum ΔP are given in Table 4. Because of the nature of the pressure waveform for demand type UBA's, maximum ΔP is not considered appropriate for setting goals in category 1 and 2. In categories 3-5, the UBA will usually obey Bernoulli's law:

$$\Delta P_{max} \propto (\dot{V}\ max)^2\ P.\rho$$

$\dot{V}$ max = peak flow
P = ambient pressure (ATA)
ρ = gas density at 1 ATA
ΔP max = max Δp (from neutral to full inhalation or exhalation)

Also for a sine wave input
$$\text{breathing work/L} = \frac{\pi\ \Delta P\ \text{max}}{200}$$

Thus once a ΔP max is chosen under one condition, in categories 3-5, the ΔP maximum and work-of-breathing are defined under all other conditions.

B. UBA Performance Goals (Tolerance is ± 10% of stated values)

Category 1: Breathing gas: Air
Maximum work-of-breathing is not to exceed 0.14 kg-m/ℓ at all depths and RMV up to and including 132 FSW and 62.5 RMV with 1000 psig supply pressure to the regulator first stage (see Note 1).

Category 2: Breathing gas: Air
(a) Maximum work-of-breathing is not to exceed 0.18 kg-m/ℓ at all depths and RMV up to and including 132 FSW and 62.5 RMV with supply pressures as per manufacturers requirements.

Breathing gas: HeO_2
(b) Maximum work-of-breathing is not to exceed 0.18 kg-m/ℓ at all depths and RMV up to and including 1000 FSW and 62.5 RMV with supply pressures as per manufacturers requirements (see Note 2).

(c) End inspired CO_2 levels at the mouth should be no greater than 2 mmHg more than the supply gas CO_2 at work rates up to 62.5 RMV at depths to 132 FSW on air and at depths to 1000 FSW on HeO_2 breathing gas, respectively.

Category 3: Breathing gas: Air

(a) Work-of-breathing is not to exceed 0.22 kg-m/ℓ and peak inhalation and exhalation presures are not to exceed 14 cmH_2O in either direction at depths to 200 FSW and 75 RMV (see Note 3).

(b) At the lowest driving pressure and longest umbilical length, gas flow rate to the UBA must be sufficient to maintain inhaled CO_2 less than or equal to 2.0% surface equivalent value at work rates up to and including 3.0 LPM CO_2 injection at 75 RMV.

(c) Helmet sound level is to be less than 90 dBA.

Category 4: Breathing gas: Air

(a) Work-of-breathing is not to exceed 0.18 kg-m/ℓ with peak inhalation and exhalation pressures not to exceed 11 cmH_2O in either direction at 75 RMV and 150 FSW (see note 3).

Breathing gas: HeO_2

(b) Work-of-breathing is not to exceed 0.22 kg-m/ℓ with peak inhalation and exhalation pressures not to exceed 14 cmH_2O in either direction at 75 RMV and 1500 FSW (see note 3).

(c) Static lung loading with no gas flow in the breathing loop should be 0.0 cmH_2O relative to the suprasternal notch in the upright position and + 10.0 cmH_2O in the prone position (see Figure 2).

(d) End inspired CO_2 levels at the mouth should be no greater than 2 mmHg more than canister effluent at work rates up to and including 3.0 LPM CO_2 injection.

(e) Helmet sound level to be less than 90 dBA.

(f) Unmanned canister duration time is the mean of at least 4 individual duration times done under identical conditions. The individual duration times are the times required for the canister effluent to consistently exceed 0.5% SEV during the work period of a canister duration study.

Category 5: Breathing gas: Air

(a) Maximum work-of-breathing is not to exceed 0.22 kg-m/ℓ with peak inhalation and exhalation pressures not to exceed 14 cmH_2O in either direction at 75 RMV and 200 FSW (see Note 3).

Breathing gas: HeO_2

(b) Maximum work-of-breathing is not to exceed 0.22 kg-m/ℓ with peak inhalation and exhalation pressures not to exceed 14 cmH_2O in either direction at 75 RMV and 1500 FSW (see note 3).

(c) Maximum allowable CO_2 level in the mask or helmet is to be less than 2.0% surface equivalent at work rates up to and including 3.0 LPM CO_2 injection (see note 4).

(d) Unmanned canister duration time is the mean of at least 4 individual duration times done under identical conditions. The individual duration times are the times required for the canister effluent to consistently exceed 0.5% SEV during the exercise period of a canister duration study (see note 4).

(e) Helmet sound level is to be less than 90dBA.

A summary of all performance goals in each category of UBA is given in Table 5.

Note 1: This goal is based upon a recent NEDU Report 2-80, "Evaluation of Commercially Available SCUBA Regulators", March 1980, by James R. Middleton, which evaluated commercially available SCUBA regulators. Only seven regulators met the above goal with another 23 being close. The value of 0.14 kg-m/ℓ at 62.5 RMV and 132 FSW was determined by examining the data to find the point at which state-of-the-art equipment significantly outperformed the rest of the group. The 75 RMV goals of Categories 3-5 is not attainable in Category 1 and 2 UBA's; and, consequently, the categories have performance goals with shallower depths and lesser RMV's than do Categories 3-5.

Note 2: The value of 0.18 kg-m/ℓ at 62.5 RMV represents the maximum performance that can be expected from state-of-the-art equipment in Category 2. It is based upon unmanned tests performed at NEDU.

The performance goal differs from Category 1 because conventional SCUBA regulators receive gas at the second stage at 125 to 150 psig overbottom pressure. Most demand regulators in Category 2 have overbottom pressure set at approximately 135 to 180 psig O/B at the diving console. The UBA then receives gas to the second stage at only 75 to 115 psig overbottom due to pressure losses in the umbilical and mask side block. Consequently, it is reasonable to expect a slightly reduced level of performance in Category 2 compared to Category 1.

Note 3: 75 RMV has been proven in both manned and unmanned testing as a reasonable performance goal in Categories 3 through 5. It will insure that the UBA is not the limiting factor in diver performance.

Note 4: Item (c) in Category 5 refers to ventilation sufficiency of the UBA helmet while item (d) in Category 5 refers to scrubbing efficiency of the CO_2 absorbent canister and both must be met simultaneously in this type of UBA.

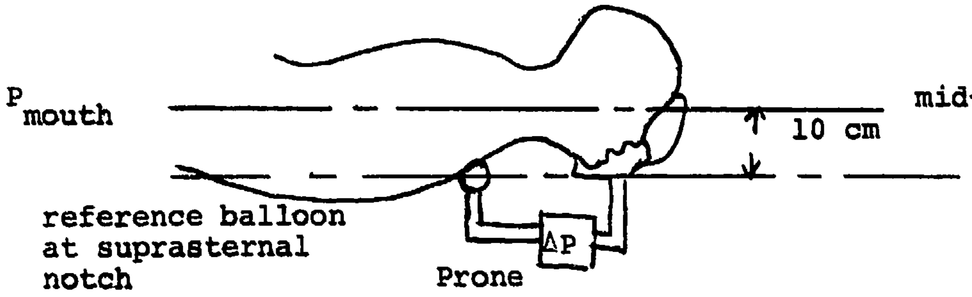
PERFORMANCE GOALS

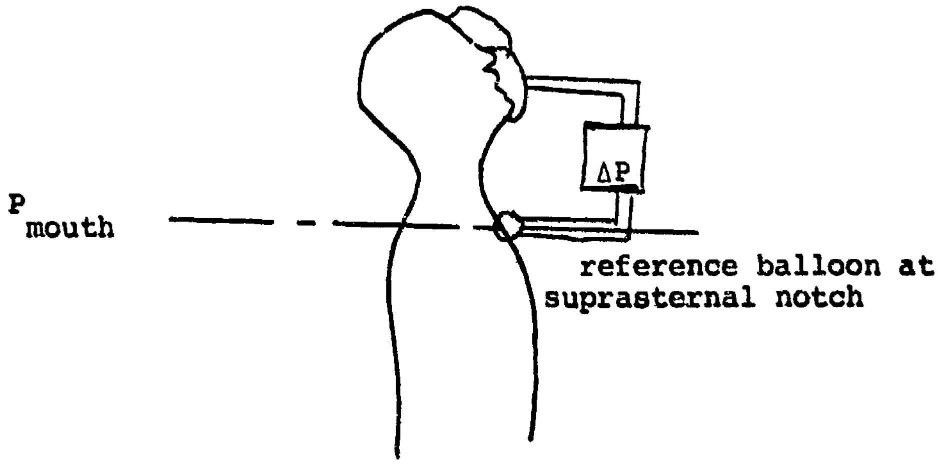
TABLE 5

					CATEGORY 1 DEPTH 132 FSW AIR	CATEGORY 2 132 FSW AIR 1000 FSW HeO_2	CATEGORIES 3&5 200 FSW AIR 1500 FSW HeO_2		CATEGORY 4 150 FSW AIR		CATEGORY 4 1500 FSW HeO_2	
LPM	RMV LPM	TV ℓ	FREQ	PEAK FLOW RATE LPS	Work/ℓ kg-m/ℓ	Work/ℓ kg-m/ℓ	ΔP** CmH20	Work/ℓ kg-m/ℓ	ΔP** CmH20	Work/ℓ kg-m/ℓ	ΔP** CmH20	Work/ℓ kg-m/ℓ
0.90	22.5	1.5	15	1.18			1.5	0.02	1.1	0.02	1.5	0.02
1.60	40.0	2.0	20	2.09			4	0.06	3.3	0.05	4	0.06
2.50	62.5	2.5	25	3.27	0.14*	0.18*	10	0.15	7.6	0.12	10	0.15
3.00	75.0	2.5	30	3.93			14	0.22	11.0	0.18	14	0.22
3.60	90.0	3.0	30	4.71			20***	0.32	16.4***	0.25	20***	0.32

*Categories 1 and 2 are not capable of making the 75 RMV performance requirements at their maximum operating depths. State-of-the-art in open-circuit demand UBA is such that 62.5 RMV is the absolute limit for reasonable breathing work values at the present time.
**ΔP max is measured from neutral (no flow) to full inhalation or exhalation.
***3.60 V_{O_2} and 90 RMV is of data interest but 75 RMV is the actual performance goal.

FIG. 2





Upright

In the prone position, the no-flow mouth pressure (P_{mouth}) should be the same as the hydrostatic pressure at the mid-thoracic line. A differential pressure transducer (ΔP) connected between the oronasal mask and a pressure reference balloon at the suprasternal notch would read +10 cm H_2O since the suprasternal notch is usually 10 cm below the mid-thoracic line.

In the upright position, P_{mouth} should be at the same level as the suprasternal notch so that a differential pressure tranducer connected between the oronasal mask and the reference balloon would read 0 cm H_2O.

References

1. NEDU Report 2-78, "Second Manned Evaluation of the Prototype Mark 12 SSDS Helium-Oxygen Mode," R.K. O'Bryan

2. NEDU Report 4-78, "Maximal Work Capacity of Man at 43.3 ATA," R.K. O'Bryan

3. NEDU Report 11-78, "Manned Evaluation of MK 1 SLSS," J.L. Zumrick

4. NEDU Report 13-78, "Manned Evaluation of the Mark 14 Closed-Circuit Saturation Diving System," J.L. Zumrick

5. NEDU Report 5-79, "Evaluation of Modified Draeger LAR V Closed-Circuit Oxygen Rebreather," James R. Middleton

6. NEDU Report 9-79, "Evaluation of the Diving Systems International Superlite 17B Helmet," James R. Middleton

7. NEDU Report 2-80, "Evaluation of Commercially Available Open-Circuit SCUBA Regulators," James R. Middleton

8. NEDU Report 3-80, "Unmanned Evaluation of U.S. Navy MK 11 Mod 0 Semi-Closed-Circuit Mixed-Gas UBA," James R. Middleton

9. NEDU Report 5-80, "Improved Life Support Capability of the MK 11 Semi-Closed-Circuit UBA by Modification of the Carbon Dioxide Absorbent Canister," C.A. Piantadosi, E.D. Thalmann, and W.H. Spaur

10. NEDU Report 9-80, "Unmanned Evaluation of U.S. Navy EX-16 UBA Pre-Production Model," James R. Middleton

11. NEDU Report 13-80, "Manned Evaluation of the Pre-Production MK-16 UBA," C.G. Gray and E.D. Thalmann

12. NCSC Hydrospace Lab Note #33-77 MK 12 SSDS Flow Test (Air Mode)

13. NCSC Hydrospace Lab Note #3-77 Recirculator System Flow Test (MK 12 SSDS Mixed Gas Mode)

14. NCSC Hydrospace Lab Note #9-77 MK 12 SSDS Total System Flow Test Series II

Appendix A

Reports Superceded by NEDU Report -81

1. NEDU Report 19-73, "Proposed Standards for Evaluation of Breathing Resistance of Underwater Breathing Apparatus," 1-30-74, S.D. Reimers

2. NEDU Report 23-73, "USN Procedures for Testing Breathing Characteristics of Open-Circuit SCUBA Regulators," [illegible]-11-73, S.D. Reimers

3. NEDU Report 19-74, "Testing Procedures for Closed-Circuit and Semi-Closed-Circuit Underwater Breathing Apparatus," 1-29-74, S.D. Reimers

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